

Submission on:

“Broadband Connect”

and

“Clever Networks” Programs

From

**The ARC Special Research Centre for
Ultra-Broadband Information Networks
(CUBIN)**

and

National ICT Australia (NICTA)



Scope of this Submission

This submission by CUBIN and NICTA is a description of likely future developments in broadband communications to inform Broadband Connect and Clever Networks program design and regional, rural and remote access policy development.

CUBIN

CUBIN is the ARC Special Research Centre for Ultra-Broadband Information Networks. CUBIN has been funded by the Australian Research Council since year 2000 and focuses on research and teaching of broadband information technologies. CUBIN is located in the Electrical & Electronic Engineering Department at the University of Melbourne. The aim of CUBIN is to advance fundamental theory and to develop a practical basis for the design, implementation and management of Ultra-Broadband Networks.

CUBIN’s vision is the realisation of ‘Gigabit to the User’ and, during the next three years, one of CUBIN’s key research topics is ‘Broadband to the Bush’. CUBIN goal in making this submission jointly with NICTA is to highlight new technology developments and to identify how they relate to currently available broadband communication technology.

NICTA

National ICT Australia (NICTA) was established in 2002 to drive innovation through high quality research and technology transfer. NICTA generates national benefit through research, commercialisation, education, and collaboration in information and communications technology (ICT).

NICTA’s Network Technologies Program is undertaking multi-disciplinary research into intelligent measurement for network automation and developing new network technologies required for ultra-broadband networks of the future. The Broadband to User (B2U) project covers both passive optical network (PON) access systems and millimetre wave wireless systems operating around 60GHz.

NICTA’s Networks and Pervasive Computing Program Networking conducts research into protocols for providing seamless connectivity with the goal of developing mechanisms needed to provide efficient data transfer over networks with diverse characteristics, improving the performance and supporting new applications - sensor, P2P, and applications with QoS constraints. The Integrated ICT Solutions for Rural and Remote Access (Office in a Box) project addresses a combination of VoIP and data compression technologies to enable a cost effective gateway for remote SME & SOHO communications.

Introduction

The purpose of this submission is to provide an overview of emerging broadband technologies to inform future policy direction and program design. CUBIN and

NICTA strongly support the Australian Government’s position to develop a flexible and technology agnostic approach in the Broadband Connect and Clever Networks Programs.

NICTA and CUBIN are happy to provide further technical advice if required.

Recommendations

1. A long term demographic forecast should be used to guide appropriate broadband network infrastructure development in regional Australia to ensure future proofing of such development initiatives
2. Town planning initiatives of shires and city councils in regional areas should take a proactive role by making the provision of broadband network cabling infrastructure a part of any medium to high density property developments
3. The deployment of broadband to regional Australia is fundamentally a commercial question not a technological one, policy to develop Broadband deployment should be based on a strong platform of economic and market analysis to inform research, technology rollout, services development as well as public policy and expectations on accessibility
4. Current technologies deployed in the next three years for broadband services outside urban areas should be regarded as transitional, pending the arrival of new broadband and ultra-broadband systems in the three to ten year timeframe
5. Objectives for access to broadband as a national infrastructure strategy should be based on economic and demographic analysis such that access to ultra-broadband is available for all population centres exceeding 10,000 people
6. The research and development of broadband access technologies in Australia should be accelerated to maximise the potential return to the country through both broadband technologies and services. Specific measures could include:
 - Test beds to develop commercially viable Australian implementations of new broadband technologies such as the integration of WiMAX with optical access
 - A program of field trials in rural, regional and remote areas

Question 4, 5 – Satellite

Q4: Is terrestrial or satellite the most appropriate means of delivering broadband in regional, rural and remote areas?

Q5: Can satellite be delivered as competitively as terrestrial services?

Answer 4:

A combination of terrestrial and satellite technologies needs to be considered in order to provide the most effective solution for regional, rural and remote areas. It is

important to note that different technologies may be used for backhaul and for local access and that it is important to also consider means of maximising the effectiveness of backhaul by providing intelligent gateways which will enable efficient access for remote communities.

Answer 5:

Recently launched satellite systems which are described in answer to Q12 provide a basis for increasing the use of satellite solutions. Additional technology enhancements provided by intelligent application gateways will ensure that satellite is a competitive solution.

Question 12 – Specific Technologies

Q12: On what basis would you argue that certain specific technologies will have the most impact on the delivery of regional broadband services in the next three to five years?

Answer 12:

A number of new technologies are rapidly changing the economics of broadband delivery in both urban and non-urban areas. In particular, a trend is emerging that will, within a few years make ultra-broadband data services available in all but the most remote areas.

Below is a discussion of the existing and emerging technologies that are contributing to this change. More detail on new technologies is provided in the answers to subsequent questions.

Optical Fibre Backbone

In areas of sparse population density, optical fibre is best suited to carry aggregated traffic between small numbers of places due to the relatively high cost of laying the fibre. This “backhaul” strength makes optical fibre the ideal way to provide ultra-broadband capacity to rural townships.

Optical fibre’s capabilities mean that virtually any desired capacity can be provided by suitable choice of the terminating equipment at each end of the fibre.

Optical Fibre Access

Optical fibre access to individual businesses and houses must be regarded as the ultimate solution for broadband service provision. The capacity of optical fibres is sufficient to provide for all imaginable services for homes and businesses.

Broadband delivery via optical fibre can be realised through passive optical networks (PONs) where a network comprised of passive optical fibre cables and optical splitters can be used to interconnect multiple optical network units (ONUs) with a central office. In such a network, optical network units located at customer premises or at a location close to them will act as the gateway to a broadband network.

Fibre to the X (FTTX) solutions can be developed where X denotes the location of the remote optical network units and it can be either at the home (in the case of ultra-high density living areas) or at the premises (in the case of a multiple dwelling units or business parks of small/medium enterprises or on a pole (in medium to low density living areas). In the case of optical network units being located at a shared access point away from individual customers (i.e. pole or premises), cost-effective hybrid broadband access can be enabled by combining optical fibre with other conventional access solutions such as coax, copper and wireless. Again any desired capacity can be supported if it makes economic sense. PON based optical fibre access solutions can provide a future proof basic telecommunications infrastructure on which further upgrades and development can be based in an incremental manner.

The provision of direct optical fibre access to the customer premises to realise fibre-to-the-home (FTTH) solutions is being actively evaluated around the world for dwellings located in medium to high density urban areas. FTTH solutions are being increasingly explored as part of new property development where property developers provide the optical fibre cabling infrastructure together with other common utility connections to the lots. Such initiatives make FTTH solutions more economically feasible in green field sites.

Given the future proofing advantage offered by optical fibre, FTTX solutions where fibre access is provided to a remote location closer to the customer premises and shared by a bigger number of customers seems very feasible for low to medium density dwellings. When the deployment of such solutions in urban areas are accelerated, deployment of FTTX solutions to remote towns and regional population centres can become economically feasible in the next three to five year period. Optical fibre access can also be used within a town to provide high capacity communication to local business and to switching centres of mobile telephone base stations. The effectiveness of FTTX solutions in the context of broadband access to the rural areas lies in its unique advantage of future proofing and the integration of other solutions in the last mile such as ADSL, Wi-Fi and WiMAX in the next 3-5 year period.

Copper and DSL

Digital Subscriber Loop (DSL) and in particular Asymmetric Digital Subscriber Loop (ADSL) have become the most cost effective way of providing fixed broadband services to households and small business. Innovations in technology and cost reductions through increases in scale of manufacture have increased the available bit rates and reduced the costs of ADSL.

ADSL is likely to be the most economic means of supplying broadband services to fixed locations in rural towns. Technical limitations prevent current DSL technology from reaching more than 4 kilometres to 6 kilometres from an ADSL equipped exchange.

Wireless Broadband

Wireless broadband systems are currently most commonly found in local area networks (LANs). During the past few years LANs have expanded from business premises to homes and to public places. Wi-Fi is a wireless LAN service based on standard wireless Ethernet (IEEE 802.11) and is now widely available in the central

business district and “hot spots” in airports, shopping centres, university campuses, etc.

There is an increasing trend in the US and now beginning in Europe to provide complete coverage of major city central business districts. In many cases, the local council is promoting this network build as a way of providing broadband services to the underprivileged and to government workers. This could be done in any rural town. The amount of money available will determine the extent of the coverage.

Typical users of Wi-Fi are laptop computer users. New devices are under development to take advantage of the growing Wi-Fi networks, including Personal Digital Assistants, “Blackberry” style handheld email devices and even mobile phones.

Normally mobile phones use the mobile telephone network which is primarily narrowband (<64 kbit/s). Some new ‘Wi-Fi phones’ are becoming available with both mobile telephony and Wi-Fi data capability. Motorola introduced a third-generation, or 3G, cellular mobile telephone with Wi-Fi capability for Japan in 2005. Nokia, the world's No. 1 mobile-phone maker, has also recently launched a Wi-Fi model. Samsung Electronics is developing one. Sprint Nextel, the No. 3 U.S. mobile carrier, is preparing to introduce a hybrid mobile/Wi-Fi service in 2006.

Satellite Communications

Recent advances in satellite technology have enabled the development and launch of a number of new satellite systems, based on native standard Internet Protocol (IP) technology. The newly launched systems, e.g. Inmarsat BGAN and IPSTAR offer significantly lower priced end-user equipment and airtime, and have significantly higher available bandwidth. For IPSTAR, this is comparable to large satellite installations with the available end user bandwidth in Mbit/sec range and the indicative cost of terminal lower than \$300 and airtime prices on par with ADSL.

Inmarsat BGAN has bandwidth comparable to 3G mobile technology (480kbit/sec) and is a mobile data device compatible with standard SIM cards and with airtime an order of magnitude lower than the current Inmarsat systems. Both of these systems have highly efficient transmission technologies, based on high powered small spot beams, with frequency sharing and coordination done on a system level and with cutting edge modulation and coding technologies which make extremely efficient use of the available bandwidth. This enables the basic transport of data in a cost effective way, compared to the cost of terrestrial technologies in a number of remote areas.

Local access may be provided by other means described in this section, i.e. by wireless or wired access within a local geographical area which covers the community sharing the access network. An intelligent applications gateway can further increase the effectiveness of satellite communications technology. The intelligent gateway would provide efficient IP telephony (voice over IP) and data transmission and compression technologies, caching of content to cater for groups of users, all of those optimised for satellite access and delays. A number of new technology enhancements are emerging in this area, and various options may also be applied to terrestrial access technologies.

Mobile Communication

Although mobile communication has been driven by voice, it is inherently a digital data system. Data traffic, in the form of email, image transfer, web browsing and video, is increasing as a proportion of total traffic on mobile telephone networks. How the different mobile technologies handle the data traffic will be the key differentiator of their effectiveness in the future.

Third generation (3G) wireless cellular radio networks are currently being rolled out around the world. These networks provide new services to mobile phones, such as audio and video streaming, gaming, and web browsing that were not previously available with second generation (2G) networks.

Although these new networks provide greater bandwidth, and a wider range of services, in comparison to the previous 2G networks, they are still far from the intrinsic capacity limits predicted by information theory. They can't be considered to be real broadband services.

Question 13 – Technology Effectiveness

Q13 How would you compare the effectiveness of these technologies to others in the market place?

Answer 13:

Optical Fibre

Optical fibre is the most appropriate technology for long distance communications and even short distances on a point-to-point basis where required capacity is high. If we consider a small town located in the country areas, optical fibre will be used to carry traffic to the town. This backbone network will be designed with at least two paths into the town so that a single fibre cut will not cut the entire town off the network.

Connecting towns via optical fibre access is crucial to enabling rural communities with access to a rich array of broadband services and making the investment future proof. Connecting regional population centres via a secure national fibre backbone network must be part of the strategy for providing broadband to regional Australia. Deployment of an optical fibre cable network can be achieved via a combination of underground cabling and overhead or aerial fibre optical cabling.

There is no other technology more effective for backbone communication.

FTTX – Optical Fire Access

While the economic feasibility of direct customer access to optical fibre (e.g. fibre-to-the-home, FTTH) in rural areas may not have been established, other FTTX solutions should be actively considered as part of the technology evaluation. Optical fibre access can be used within a town to provide high capacity communication to local business and to switching centres of mobile communication facilities.

For remote towns with an optical fibre backhaul, it may be feasible to consider solutions that integrate ADSL, Wi-Fi or WiMAX to provide the last mile access. In

the case of medium to large towns, implementation of PON could help with the roll out of high speed ADSL by enabling the positioning of the ADSL access multiplexers closer to the customers (see below). Alternatively, a WiMAX service could be delivered via a network of access points interconnected via a PON.

Copper and DSL

Many countries have multi-megabit per second (Mbit/s) commercial ADSL services widely available. For example in the USA, BellSouth introduced in November 2005 an ADSL service with 6 Mbit/s downstream speed and 512 kbit/s upstream speed for US\$46.95 per month.

AT&T in the USA also offers download speeds of 6 Mbit/s in a service incorporating a range of add-ons for US\$64.99 per month. Verizon offers a 3 Mbit/s service for \$29.95 per month. In the UK, BT offers a 2 Mbit/s service for £17.99 per month.

Australia lags many countries in the widespread availability of cheap multi-megabit per second ADSL services.

ADSL has proven to be the most effective broadband access technology. There were over 200 million broadband lines in service around the world at the end of 2005. Around 140 million of these were ADSL and the proportion is continuing to grow. Even in the USA where cable modems on hybrid fibre coax networks dominated broadband access due to the extensive Pay TV infrastructure, ADSL penetration has virtually caught up.

Mobile Broadband Communication

Mobile, or cellular communications systems have historically been designed with voice traffic in mind. The patterns associated with voice communications are well known, having been observed since the invention and widespread use of the telephone. Voice can be characterized as relatively predictable, with each party talking about half the time in an interactive manner. The statistics of call duration and time of day are well understood. This allows traffic engineers to use a standard methodology to estimate the amount of capacity needed in a communication system.

The fixed telephone network has been engineered in a hierarchical fashion using large circuit switches to efficiently connect one voice user to another. The physical circuit over which a call is made is held open for the entire duration of a call, hence the term circuit switching.

Telephony in fixed and mobile settings has similar characteristics. Existing cellular telephone systems have therefore been designed in a similar way, and optimized to efficiently provide voice service.

Data traffic differs from circuit voice in a number of important ways.

Firstly, data traffic is much more unpredictable than voice traffic. Data is characterized as 'bursty', meaning that there is significant variability in when the traffic arrives, the rate at which it arrives, and the number of bits in the messages. Generally, there are many users simultaneously sharing network resources in a sporadic manner. The network traffic that results is bursty in nature with the mix of applications, message sizes, throughput needs, and delay sensitivity. Efficiencies are realized through statistical multiplexing achieved by packet switching.

Secondly, data has very different requirements in terms of reliability. Whereas voice is very robust and capable of being understood even in a noisy environment with a high bit error rate well above 1%, data applications require extremely reliable delivery, with virtually no tolerance for bit errors. Because some bit errors are unavoidable on wireless links, it is important that fast and efficient recovery schemes are implemented to get the correct data bits to the application. A combination of forward error correction and fast acknowledgements satisfies this need. Powerful forward error correction is employed to dramatically reduce the bit error rate, and fast acknowledgements are used to guarantee reliable delivery.

Thirdly, a data service can be characterized by its importance or priority. This is determined by the quality of service (QoS) that is required, which can be measured by the amount of delay that a user is willing to tolerate, and the reliability required. A service provider may offer differing service rates, or classes of service, accordingly. Premium service users may be given priority over best-effort users, whose traffic is sent if there is capacity available at the time.

A final aspect of a data service is latency, or response time. This determines the degree of interactivity that can be achieved, which is a measure of how quickly channel resources can be assigned at the request of a user.

Many feel that data services differ from voice in one other way, which is related to the variability in capacity demanded by the end user. If data users are allowed to consume as much bandwidth as they can, provided that there are no higher priority users contending for resources, a system will tend to always be in a state of high utilization. The admission control mechanism, which governs how users access the system and how they are allocated resources, becomes a potential bottleneck under such circumstances. In order to provide low latencies in a wireless environment, where errors are unavoidable and packets must be retransmitted, it is necessary for a system to employ a fast acknowledgement capability so that packets received in error can be quickly retransmitted.

Third generation mobile services are able to support peak data rates exceeding 100kbit/s. However, the headline data rate can be a misleading indication of a technology’s “throughput” capabilities. Peak data rate is the maximum data rate achievable under ideal radio conditions and is normally only possible close to the centre of the cell site. The further away from the centre of the cell and in weaker radio coverage areas such as indoors or deep fading situations, peak data rates will be lower.

In addition, it is often not understood that quoted data rates are not the actual data rates that will be experienced by multiple users. Since the peak data rate is only actually deliverable in 5% -10% of the cell area, for one active subscriber, it is not a justifiable metric to use for assessing the viability of any technology. Peak data rates are a measure of maximum performance, but do not have the greatest impact on individual or average customer experience.

With some technologies, efficiency declines as the network is loaded due to increased interference resulting in an increase in latency. The cell data rate is a shared resource that is used by all active users in the cell at any one time. The difference is that users are often moving so actual user data rates will vary across the cell area. The closer to the centre of the cell, the higher the data rates, and the further away, at the cell edge, the lower the data rates.

Mobile Data Usage and the Internet

Unlike connection-oriented networks such as used for telephony, connectionless packet data networks such as the Internet do not deliver one circuit to one user for the time it is needed. Customers share the network resources. TCP/IP, the underlying transport/networking protocol, manages the end-to-end scheduling and allocation of how much of each “pipe” each user gets.

When mobile networks are used to carry data, usage can be a few bytes of e-mail, a download of a web page, a short transaction with a remote server or an FTP (File Transfer Protocol) download of a large file. When evaluating any data access technology it should be remembered that browsing is still a primary service on the Internet. Supporting web service economically requires the ability to support a large number of short HTTP transfers per unit of time to a large subscriber population. Hence, when assessing the viability of a mobile broadband technology for delivering packet data services, it is important then not to fall into the trap of simply downloading a large file of some tens or hundreds of Megabytes and measuring the time it takes.

Connection-oriented access technologies such as those based on CDMA typically perform much better in FTP tests than with short, bursty data type of services such as simple e-mail, messaging or browsing. This is because the transition time – the period it takes the system to bring the device out of the *Sleep* state and into the *On* (Send) state – can take seconds. Long state transition times are very inefficient when sending or receiving small amounts of packet data since the transition time from *Sleep* to *On* is often longer than the time taken to actually send the data.

Actual performance depends on a radio access technology’s ability to support TCP. Issues such as latency, number of Active and On users and transition time between states has a greater impact on performance and capacity than does the peak data rate.

Question 14 – Meeting Increasing Demands

Q14 To what extent will broadband technologies be able to augment capacity to meet rapidly expanding consumer expectations for higher bandwidth and more advanced applications?

Answer 14:

Optical Fibre

The useful capacity of optical fibres is continuing to grow. Within a short time commercial systems will be able to support hundreds of wavelengths, each carrying up to 40 Gbit/s (40,000 million bits per second). Even if every user requires a dedicated 1 Gbit/s, a single fibre of this capacity could support tens of thousands of users. This means that a single fibre could theoretically support a reasonable sized country town even if every household and business in the town simultaneously required a thousand times the capacity currently considered to be broadband.

The other advantage of optical fibre backhaul systems is that, if they are designed correctly, changes to the fibre capacity can be made by changing only the equipment at the ends of the fibre. This means that the fibre can be installed with an

economically sensible capacity and subsequently increased in capacity as user demand increases.

Optical Fibre Access

In conjunction with the backbone optical fibre links, optical fibre access integrated with other access solutions can provide a path to a graceful evolution of broadband networks in the rural and urban areas. Consideration of optical fibre access should be part of the future proofing strategy for any large scale deployments.

Copper and DSL

ADSL is a technology that is limited in both distance and speed. The higher the speed - the shorter the distance. The maximum speed of ADSL is 8 Mbit/s but this is only achievable over a few hundred metres. The maximum practical speed at a distance of 3 kilometres is around 3 Mbit/s.

New versions of ADSL have become available. ADSL 2 and ADSL 2+ offer speeds up to 24 Mbit/s but again the highest speeds have a range of only a few hundred metres. Commercial ADSL 2 offerings are available in some areas of Australia and those lucky enough to live close to a properly equipped telephone exchange can get services with a download speed of 12 Mbit/s.

Telstra has proposed a more widely available solution using optical fibre to carry signals from the exchange to a street pillar and then distributing ADSL services over copper from the pillar. This will increase the effective range of ADSL at the cost of having electronic devices in the street. In the past, electronics in the street have proven to be very costly to maintain due to environmental conditions and vandalism.

The fibre-to-the-pillar/ADSL approach will provide multi-megabit downstream speeds in larger rural communities but will be uneconomical where the population density drops below a certain level.

Question 15 – Complementary Technologies

Q15 Can complementary technologies provide better solutions for delivery of services in regional Australia?

Answer 15:

FTTX Optical Fibre Access:

FTTX based access solutions are now a commercial reality in high density urban areas in some countries such as Korea and Japan. They compete very well with VDSL (see below) services in terms of cost-effectiveness and high bandwidth. FTTH solutions are now actively pursued by green field property developers where investment in optical fibre cabling is packaged as part of the provision of other utilities to the property.

While the economic feasibility of a large scale FTTH implementation in regional areas is not yet established, FTTX solutions integrated with either digital subscriber line or wireless broadband should be investigated. For example, when the existing copper infrastructure is not suitable for VDSL service in large towns, FTTX can be deployed to make VDSL deployment in the last mile possible. Similarly FTTX can also be integrated with WiMAX service delivery. FTTX solutions could play a role in interconnecting the backbone networks and networking of shared access points in medium to large regional towns.

VDSL

Very high speed digital subscriber line (VDSL) services are commercially available in some countries. VDSL is a very short range service which works well in apartment block situations where an optical fibre carries high speed service to the apartment block and copper is used to distribute VDSL throughout the building. In Korea, VDSL has been available for two years and provides downstream speeds of 50 Mbit/s at a cost of around US\$36 per month.

VDSL is probably not a suitable technology in less densely populated areas in Australia due to its distance limitation.

Emerging Wireless Technologies

An important emerging wireless technology is *Orthogonal Frequency Division Multiplexing* (OFDM). OFDM is a modulation and multiple access technique that has been explored for over 20 years. Only recently has it been finding its way into commercial communications systems, as Moore’s Law has driven down the cost of the signal processing that is needed to implement OFDM based systems.

OFDM, or multi-tone modulation, is presently used in a number of commercial wired and wireless applications. On the wired side, it is used for a variant of digital subscriber line (DSL). For wireless, OFDM is the basis for several television and radio broadcast applications, including the European digital broadcast television standard, as well as digital radio in North America. OFDM is also utilized in several fixed wireless systems and wireless local area network products. At least one company, Flarion, has developed a prototype system to deliver a *mobile* broadband data service at comparable data rates to wired broadband services, such as DSL and cable modems.

The next (fourth) generation of cellular networks will almost certainly employ two technologies that are not present in current cellular systems. The first is orthogonal frequency division multiplexing (OFDM), described above, and the second is employment of multiple antennas at mobile units and at base stations (known as multiple-input, multiple-output or MIMO).

While there has been great progress in understanding the properties of single-link MIMO and OFDM systems, many questions remain to be answered on how best to design a cellular mobile network based on this underlying physical layer. Cellular networks built on MIMO-OFDM physical links will have an enormous amount of flexibility and will be able to support multi-megabit mobile services to hundreds of customers simultaneously.

WiMAX

WiMAX, an acronym that stands for Worldwide Interoperability for Microwave Access, is a certification mark for products that pass conformity and interoperability tests for the IEEE 802.16 standards. IEEE 802.16 is working group number 16 of IEEE 802, specialising in point-to-multipoint broadband wireless access.

WiMAX is a wireless metropolitan area network (MAN) technology that uses both OFDM and MIMO technologies. WiMAX can connect IEEE 802.11(Wi-Fi) hotspots to the Internet and provide a wireless extension to cable and DSL for last kilometre broadband access. IEEE 802.16 provides up to 50 km of linear service area range. Users without a direct line of sight to a base station can expect a range of up to 15 km. The technology also provides shared data rates up to 70 Mbit/s, which, according to WiMAX proponents, is enough bandwidth to simultaneously support more than 45 businesses with 2 Mbit/s connectivity and well over a thousand homes at 1Mbit/s DSL-level connectivity.

The network protocol is significantly different from that of Wi-Fi (and Ethernet from which Wi-Fi is derived). In Wi-Fi, the Ethernet uses contention access. All subscriber stations wishing to pass data through an access point compete for the access point's attention on a random basis. This can cause distant nodes from the access point to be repeatedly interrupted by less sensitive, closer nodes, greatly reducing their throughput.

By contrast, WiMAX uses a scheduling protocol where the subscriber station competes only once (for initial entry into the network). After that it is allocated a time slot by the base station. The time slot can grow or shrink, but it remains assigned to the subscriber station meaning that other subscribers are not supposed to use it and take their turn. This scheduling algorithm is stable under overload and oversubscription (unlike 802.11). It is also much more bandwidth efficient. The scheduling algorithm also allows the base station to control Quality of Service by balancing the assignments among the needs of the subscriber stations.

A recent addition to the WiMAX standard has been proposed which will add full mesh networking capability by enabling subscriber stations to simultaneously function as base stations. This will likely blur the initial distinction between base station and subscriber station and allow for widespread adoption of WiMAX based mesh networks.

The final IEEE 802.16 standard was ratified in November 2005, and manufacturers are already producing equipment and conducting trials around the world. For example, Intel has signed a \$1.12 billion contract for the M-Taiwan (Mobilize Taiwan) project as part of a joint effort with Taiwan's Ministry of Economic Affairs.

The company announced that it has 13 new WiMAX installations available in Europe, South America and North Asia, with 10 more Intel-sponsored networks due by year's end.

Countries including France, Mexico, the Dominican Republic, Uruguay, Spain, Ireland, Poland, Finland, Guatemala, Ukraine, Austria and Slovakia are all either in the testing phase or using WiMAX networks for a variety of uses, from basic high-speed access for homes to Internet telephony, as well as connecting businesses, schools and government offices.

For example, Voice over Internet protocol, or VoIP, services are being offered by BEC Telecom beginning in Santo Domingo, Dominican Republic, and spreading to the rest of the country. WiMAX Telecom is offering VoIP services to home users in Burganland and Austria. Trials in Malaysia, Thailand, the Philippines Indonesia and Vietnam are expected to take place in 2006.

Nokia is expecting the technology to take off as backbone, as well as in mobile networks and devices. Nokia expects the first WiMAX laptop cards to arrive in 2006 and 2007, and even low-end handsets to be supporting WiMAX connectivity by 2011.

Combined Fixed and Mobile Wireless Networks

WiMAX by no means exhausts the potential of OFDM and MIMO. Current research on these technologies promises new systems and networks that could offer combined mobile and fixed access with speeds up to 1 Gbit/s (1,000 Mbit/s).

Flarion compared the current versions of its prototype OFDM with CDMA EV-DO (broadband CDMA) systems. Under sensible assumptions, the OFDM system supports a maximum of 125 Web browsers while, under the same traffic conditions, broadband CDMA EV-DO supports only 14 Web browsers.

IP switched networks are now emerging and broadband solutions, whether they are mesh or 802.11/802.16 based are highly suited to these. The convergence of IP switching with new wireless technology means that the cost of deployment is very cheap, in comparison to 2G/3G mobile services. Services like Skype over 802.11 (WiFi) or WiMax (802.16) will allow international calls with a price range from zero to a few cents a minute (depending on whether the called party has Skype or not). This style of communication fully utilises IP switching (avoiding the infrastructure of the incumbents) and illustrates how the cost of wireless telephony will drop significantly in coming years.

Some wireless operators contend that such services will not provide the quality of service that mobile users expect however there will be a market group that will be satisfied with the service quality. It is likely that the service quality of VoIP solutions like Skype over WiMax or WiFi will improve in coming years. Another point that wireless operators make is that WiMax will not work for high mobility, WiBro, a mobile version of WiMax has been deployed in South Korea with mobile terminals of similar form factor to 3G terminals. Technical problems with high-speed mobility have been solved for speeds up to 300km/hr (Japanese Bullet train or French TGV speeds)

In summary there will be a price convergence between very cheap VoIP services like Skype over WiFi/WiMax and 3G/4G services in the coming years, this is driven by cheaper IP switching and wireless broadband designed to correctly support the IP

The possibility of combining both fixed and mobile services into a single network is exciting as it would result in incredible cost savings. Instead of building separate networks for mobile and fixed services to households, a single network could provide broadband services to both types of users. It could also potentially take advantage of existing mobile and fixed network infrastructure.

This universal service network is currently a research topic but progress over the next few years could lead to commercial opportunities in the five year plus timeframe.

Question 16 – Innovative Approaches in Broadband Connect

Q16 What innovative approaches should Broadband Connect adopt in its program design to utilise these technologies most efficiently and effectively?

Answer 16:

Given the number of new technologies that are under trial around the world, it would be sensible for the Broadband Connect program to investigate their potential for use in Australia's rural areas. A few specific suggestions appear below.

- Experimentation with WiMAX rural systems should be undertaken
- Radio spectrum should be set aside to enable the deployment of WiMAX at some point in the future
- Regional centres should be connected with a secure national optical fibre backbone network
- Test beds or field trials should be established with researchers, equipment manufacturers and service providers to develop commercially viable Australian implementations of new broadband technologies in rural, regional and remote areas

Question 17 – Potential of Existing Technologies

Q17 What capacity do existing technologies have to accommodate the introduction of new developments, such as increased speeds, usage and other applications?

Answer 17:

This has been covered in the answer to question 14.

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